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Chapter 5

PCBS IN BUILDING CAULK: HEALTH HAZARD OR REGULATORY OVERREACTION?

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ABSTRACT

Growing public concern about the past use of polychlorinated biphenyl (PCB) containing building caulk in schools has prompted expensive caulk removal projects at a time of limited public resources. Building caulk, used during construction to fill narrow gaps around windows and door frames, was often formulated with PCBs to increase its plasticity and durability. This PCB use was banned in 1978, but even three or more decades later, schools with PCB containing caulk may still have detectable levels of PCBs in indoor air. The USEPA (2010a) has expressed concern that the inhalation of these airborne PCBs may be a significant exposure pathway for children.

Despite their presence in buildings for more than 30 years, there have been no reported adverse health effects attributable to PCBs in building caulk or other building materials. Health concerns about PCBs in schools are based on results of risk assessment models that rely on toxicity factors derived from animal studies. The USEPA has opted to use animal studies for estimating PCB risk to people even though there is abundant evidence that PCBs are significantly less toxic to people than they are to animal test species. PCB numerical risk modeling for schools appears to be an instance where there has been a significant overestimation of the actual risk posed to children.

There is a considerable body of human health data derived from occupational and non-occupational settings that supports the view that human PCB toxicity is not accurately represented by the USEPA toxicity factors, particularly the cancer slope factors. This article explores human PCB toxicity by reviewing three lines of scientific evidence: 1) a closer look at the actual causes of the Yusho and Yu-Cheng rice oil poisonings; 2) a comparison of the human health effects from

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PCBs to those caused by three other common environmental contaminants; and 3) a brief review of the arguments used to support the claim of PCB carcinogenicity.

If PCBs are significantly less toxic than represented by the USEPA cancer slope factor, then expensive efforts to remove building caulk and other PCB containing materials from schools may provide no health benefit. At a time of contracting school system budgets, avoiding unnecessary expenses is an obvious priority.

Keywords: PCBs, building caulk, schools

1. INTRODUCTION

There has been growing attention to the past use of PCBs (polychlorinated biphenyls) in building materials (Herrick et al., 2004; MIT, 2007; and MADPH, 2009). Prior to 1978, PCBs were often used as an ingredient in paints, caulks and adhesives to impart plasticity and extend the anticipated useful life of the materials. Analytical laboratory chemists (ConTest, 2010) have reported they can often identify whether a sample of building caulk contains PCBs based on whether it is soft and pliable; if so, it likely contains PCBs. A caulk sample that is brittle and dry is less likely to contain PCBs. Despite concerns about their health effects, PCBs remain faithful to their original function.

In 1978, the USEPA promulgated new regulations (40 CFR 761) banning the continued use of PCBs in many products, including building materials. As described in the introduction to the regulations, EPA scientists understood that PCBs had been used in building materials; but the agency chose not to focus further regulatory attention on this issue. Instead, EPA focused their regulatory efforts on: 1) stopping the production and continued distribution of PCBs in commerce; and 2) taking steps to identify and regulate the remaining stock of liquid PCBs. Then, as now, the bulk of liquid PCBs are found in electrical equipment such as transformers and capacitors. EPA identified the greatest risks as those arising from the mismanagement of liquid PCBs, particularly in electrical equipment.

By the early 1990s, environmental scientists were publishing accounts of PCBs being detected in indoor air, with much this early work taking place in Germany (Benthe et al., 1992; Balfanz et al., 1993). Since PCBs are a mixture of chemicals with similar structure, there is no single indicator parameter that accurately communicates their degree of volatility. There are however significant trends: overall PCBs have low volatility and the lower chlorinated species, or congeners, are considerably more volatile than the higher chlorinated congeners (Foreman and Bidleman, 1985). Although their vapor pressure is quite low, it was shown that low concentrations of PCBs could volatilize out of building materials

and into indoor air. A survey article on the state of PCB testing in indoor air appears in Spengler et al's 2000 Indoor Air Quality Handbook.

In the ten years since 2000, there have been increasing reports of PCBs in building materials and indoor air, particularly in schools (Daley, 2009; Egbert, 2008). It is likely that PCBs are being found in schools with a high frequency because investigators have focused more effort looking for them there. At this time there is no reason to suppose that PCBs occur with greater frequency in schools than they do in other buildings.

To date there have been no studies linking the presence of building material derived PCBs to actual adverse human health effects. Concerns about possible health effects arise from numerical models that use as inputs values for PCB concentration, exposure assumptions and toxicity factors to predict carcinogenic risk. As discussed in the present article, this approach to PCB risk prediction is problematic and prone to overestimating actual risk. The primary sources of modeling error are: 1) the presumption that the congener mixture present in indoor air is of similar chemical make-up as the one used to derive the cancer slope factors (Prignamo et al., 2006); and 2) that humans respond physiologically to PCBs in a manner similar to the test species (rats) used to derive the cancer slope factors (Johnson, 2006).

It is the thesis of this article that numerical risk assessment, as used to characterize cancer risk to people from PCB exposures to indoor air, significantly overestimates that risk. The extent of the overestimation is so large that it prompts the misallocation of resources towards unnecessary remedial action.

2. MATERIALS AND PROCEDURE

It is a fundamental tenet of toxicology (Menzel and Smolko, 1984) that the data used to predict toxic effects in a species of interest should be developed using a test species that is as biochemically and physiologically close to the species of interest as possible. Humans are most often the species of interest and it is usually unethical to use humans as the test species in toxicological studies. However, in the case of PCBs, there are tens of thousands of well documented human exposures described in the literature that often include thorough long term medical follow-up (Swanson et al., 1995). This human data is from occupational and environmental exposures. This human data should be of obvious importance in evaluating possible human health effects.

To assess carcinogenic risk from PCBs, the typically requires the use of the IRIS web site as the source for cancer slope factors (USEPA, 2010b). The IRIS database includes a presentation on carcinogenicity that discusses a few studies

involving human exposures, but concludes that the results of these studies are "inconclusive" and "inadequate". IRIS therefore relies entirely on the results of animal studies that use rats as the basis for deriving cancer slope factors. IRIS does not explain that the liver tumors seen in rats following exposure to PCBs do not have human physiological counterparts. The rat liver (and rodent hepatic system more generally) is physiologically different from the human (and primate) liver (Johnson, 2006), and rats appear to be more susceptible to PCB toxicity than are humans.

This article considers three lines of human based toxicological evidence that support the thesis that PCBs are less toxic than is represented in the IRIS database. The first line of evidence is from a re-examination of the Yusho and Yu-Cheng rice oil poisonings; the second line of evidence is a comparison of the known toxic effects of PCBs to those arising from asbestos, lead and radon; and the third line of evidence is to review the human data for indications of whether exposures to PCBs have resulted in human cancers.

3. INFORMATION AND DISCUSION

The information presented in this section is divided into three subsections, each representing a line of human evidence concerning the toxicity of PCBs.

3.1 Yusho and Yu-Cheng Rice Bran Oil Poisonings

The signal event that brought PCBs to world attention was the 1968 Yusho mass poisoning incident in Japan (Pfafflin and Ziegler, 2006). This tragic incident occurred when a brand of cooking oil became contaminated by heat exchange fluid. While little known in North America, rice bran oil is a popular type of cooking oil in Asia, valued for its healthful properties. The toxic rice bran oil was prepared by a process that included the use of an industrial heat exchanger containing PCB heat transfer fluid. The heat exchanger leaked and the PCB heat transfer fluid contaminated the rice bran oil. The contaminated oil was sold to consumers who used it in food preparation. The oil's consumers experienced health symptoms that began as skin lesions and spread across physiological systems resulting in pronounced and horrific toxicity. The results were effectively irreversible.

Ten years later in 1978 an eerily similar poisoning with rice bran oil occurred in Taiwan. The circumstances and particulars of the two poisonings were nearly identical.

The initial assessment of the Yusho poisonings concluded that the PCBs from the heat exchange fluid had caused the toxic effects. However, as analytical

chemists began to test the fluid, a much more complex story emerged (Kuratsune et al., 2007). A test of the rice oil based on the analysis of total organic chlorine indicated that 3,000 mg/kg of PCBs should have been in the oil; but when the same sample was analyzed by gas chromatography, there were only 1,000 mg/kg of PCBs. What could explain the presence of the remaining organic chlorine?

More testing found the rice oil contained a range of chlorinated organic chemicals, most notably polychlorinated dibenzofurans (PCDFs) and polychlorinated quaterphenyls (PCQs). PCDFs are chemically similar to PCBs, but contain a single oxygen atom bridge between carbons 2 and 2' that replaces either the hydrogen or chlorine substitution. PCQs are dimers of PCBs. Testing showed that neither PCDFs nor PCQs would have been present in significant concentrations in the original PCB heat transfer fluid.

Where did the PCQs and PCDFs come from? It turned out that when PCBs were heated above 250^{o}C (about 450^{o}F) they reacted chemically with each other and with any oxygen that was present. This reaction was catalyzed by the presence of metals (including iron) and was greatly accelerated by the presence of even small amounts of water.

To this day there has been little if any toxicity testing on the PCQs, although it is believed that they have a low order of toxicity. By contrast, PCDFs have been very well characterized and are generally considered to be among the most toxic chemicals ever discovered. PCDFs are structurally similar to the highly toxic polychlorinated dibenzodioxins (PCDDs). PCDFs are often cited as being between 10,000 to 100,000 times more potent than PCBs on a mass-to-mass basis.

To aid in evaluating the relative toxic potency of chemical mixtures containing PCDDs, PCDFs and/or PCBs, toxicity equivalence factors (TEF) have been developed for each of the individual congeners. The relative toxicity of a mixture may be estimated by multiplying the concentration of each congener times its TEF and then summing these products. When the TEF calculation was made for the Yusho rice oil, it was demonstrated that the vast majority of the oil's toxicity can be explained by the presence of just two chemicals in the oil: 2, 3, 7, 8-tetrachlorodibenzofuran and 2, 3, 4, 7, 8-pentachlorodibenzofuran. While present at much higher concentrations, it was concluded that the PCB congeners played no or almost no role in causing the poisonings (Dyke and Stratford, 2002).

Another observation from the Yusho and Yu-Cheng incidences that was inconsistent with known cases of occupational PCB poisoning was the severity and persistence of the symptoms. The symptoms of occupationally-induced PCB toxicity were generally reversed once the continuing exposure was curtailed. However, the victims of the Yusho and Yu-Cheng poisonings did not experience relief after the exposure was stopped. The symptoms of Yusho/Yu-Cheng

poisoning were significantly more extensive, severe and persistent than had previously been seen with human PCB toxicity. Clearly the toxicology was different at biochemical and physiological levels.

3.1.1 Could a Yusho-type Poisoning Occur due to Exposure to PCB Building Materials?

The Yusho and Yu-Cheng poisonings have been shown to have been caused by the consumption of rice bran oil that contained toxicologically high concentrations of PCDFs. While the oil also contained PCBs, we now know that they were not the significant causative agents. The commercial mixtures of PCBs manufactured in the US have been tested and found not to contain toxicologically significant concentrations of PCDFs. The temperature required to initiate the conversion of PCBs to PCDFs (250^{o}C and higher) can occur in a burning building, but do not occur in a building under normal operating conditions, even when materials are exposed to direct sunlight in a tropical setting. Therefore, under normal building conditions, there is no realistic possibility of building occupants being exposed to PCDFs from building materials. Without PCDF exposure, a Yusho type poisoning is not likely.

3.1.2 How are Exposures to PCBs in Building Materials Different?

Most of the PCB dose a person receives from building materials comes by way of inhalation. Some additional dose may be due to direct contact with dust and some may result from incidental ingestion of dust, but these contributions are relatively minor (Herrick et al., 2004). The distribution of PCB congeners in air is decidedly different from the congener mixture in the building material itself. This is because the vapor pressure of the congeners decreases with increasing chlorination (Annema et al., 1995). Congener studies of indoor air generally show that greater than 85% of the PCBs in indoor air are the mono-, di-, and tri-chloro congeners. These are generally considered the least toxic of the many PCBs.

However, in a numerical risk assessment performed in accordance with USEPA methods (USEPA Risk, 2010), these less-chlorinated PCBs are considered to have the same level of toxicity as the higher-chlorinated congeners. The partitioning of the congeners that occurs when PCBs volatilize from building materials has the effect of lessening the toxicity of the material people are exposed to, further reducing any likelihood that a Yusho-type poisoning incident could occur.

3.2 Comparison to Other Toxic Materials in Buildings

To provide the perspective from which it is easier to rationally evaluate health risk from PCB-containing building materials, it is useful to consider some of the other toxic materials frequently encountered in buildings. For this purpose it is useful to consider asbestos, lead and radon.

3.2.1 Asbestos

Asbestos may well be the most dangerous building material people have ever used (NIH, 2010). Sickness and fatalities from asbestos have been known since early times. To this day between 10,000 and 20,000 Americans die each year from asbestos-related disease and that number is still going up.

Asbestos disease is documented to have occurred from as little as a single inhalation exposure, but more commonly occurs following multiple exposures. The onset of disease is usually slow, sometimes taking decades to be identified. Asbestos-related disease is generally progressive and irreversible. Fortunately federal law requires the identification and control of asbestos building materials in schools and worker protection laws are enforced.

Unlike asbestos in building materials, disease from PCBs in building materials is unknown. There are no recorded incidents of poisoning or other adverse health effects from PCBs in building materials, despite their presence in buildings for more than half a century. Unlike asbestos disease, PCB toxicity is generally reversible.

3.2.2 Lead

This year (2010) in Nigeria more than 300 children (and many adults) were killed by lead poisoning when their drinking water supply was contaminated with mining waste water containing lead (NYT, 2010). In addition to the fatalities, many suffered from poisoning, but did not die from it.

In the United States it is estimated by the Centers for Disease Control (CDC, 2007) that 1% of all children in the nation have blood levels high enough to reduce their ability to learn. In Massachusetts, a state with strictly enforced lead laws, that number is 0.69%. Like asbestos, the toxic properties of lead have been known for some time. Benjamin Franklin wrote about the toxic effects experienced by those who drank whiskey from stills made of lead.

What is the number of children in the United States whose learning has been impaired by PCBs? There have been no reported cases.

3.2.3 Radon

Radon is a naturally occurring gas that is constantly produced in the earth as a result of the radioactive decay of uranium (ATSDR, 2010). While chemically inert, radon is radioactive and produces ionizing radiation. Radon continuously migrates out of the earth's crust and into the atmosphere. Radon's short half-life prevents it from accumulating in high concentrations, but it can be very hazardous even at low concentrations. There is no question that when inhaled, the ionizing radiation released by radon can and does result in increased lung cancer risk to people.

The USEPA estimates that between 8,000 and 45,000 lung cancer deaths per year are caused by radon gas that seeps into indoor air from the ground; the risk is generally considered to be ten time higher for smokers (USEPA, 2010c). Radon is the number one cause of lung cancer for non-smokers. The "acceptable level" of radon in indoor air is considered to be 4.0 pCi/l (pico-curies of radon per liter of air). The USEPA estimated that the increased risk for a non-smoker exposed to 4.0 pCi/l for a lifetime is 7×10^{-3}; that's 7 extra lung cancer cases per thousand people exposed. This is a very large risk by environmental standards. There is no national program to test schools for radon or to correct high radon levels if they are detected.

What is the number of lung cancer deaths caused by PCBs in building materials? There have been no reported cases.

3.2.4 Getting Perspective on Toxic Risks

The point of this comparison is to provide perspective on the differences between relatively small and large toxic risks. Asbestos, lead and radon kill and cause irreversible injuries to hundreds of thousands of people each year and the scientific literature is replete with case studies and unambiguous documentation of the harm caused. No such scientific literature exists to support the supposition that PCBs in building materials are dangerous to people. When PCB toxicity has occurred in people, it has been the result of doses thousands of times larger than could be received from exposures to PCBs in building materials. Also important is the fact that adverse health effects from PCBs are generally reversible. Health effects from asbestos and radon are generally irreversible; lead exposure in children may result in irreversible effects.

3.2.5 PCBs and Human Cancer

There is a widely held belief, frequently expressed in the popular environmental media (CWAC, 2010), that PCBs have been scientifically demonstrated to cause

cancer in people, but this is actually not true (Golden et al., 2004). PCBs have been shown to cause cancer in rodents, particularly rats. Rats metabolize PCBs in the liver in a manner that has no parallel in humans or other primates. PCBs can cause cancer in rats, not because they are geno-toxic (or mutagenic), but because they interfere with the particular functioning of the rat liver physiology. Humans have no comparable physiology and are not subject to the same type of cancer. PCB feeding studies in monkeys have failed to show a link between PCBs and cancer.

There are many well-documented epidemiological studies of tens of thousands of people (Golden et al., 2004) who have been exposed to PCBs in occupational and non-occupational settings. The PCB doses these people received were frequently thousands of times higher than would be likely to occur for a student attending a school with PCB-containing building materials. Many of the subjects of these studies have been followed throughout their lives with regular medical checkups to determine whether they were more prone to a variety of illnesses, including cancer. No pattern of increased cancer incidence or other illnesses has been reported from these studies (Shields, 2006). There is no scientific literature that supports a causal link between human cancer and PCBs.

4. CONCLUSIONS

This article has provided a preliminary examination of the hazard posed by PCBs in building caulk and other in-place PCB containing building materials. The USEPA has adopted a PCB risk assessment approach that relies largely on the results of cancer slope factors derived from studies with rats, a species know to be particularly sensitive to PCBs. In contrast, and in keeping with the fundamentals of toxicology, this article has reviewed some of the considerable data available on the health effects of PCBs on humans.

The article considers three lines of human-based toxicological evidence: 1) a reconsideration of the Yusho and Yu-Cheng poisoning incidents; 2) a comparison of the reported adverse health effects from asbestos, lead and radon to those reported from PCBs; and 3) a review of the epidemiological literature concerning the occurrence of cancer in people known to have been exposed to PCBs.

Consideration of the three lines of human PCB exposure studies did not identify a causal link between exposure to PCBs and any form of human cancer. The data available regarding human exposures to PCBs is extensive and robust. Given the divergent results from studies with rats and studies with people, good toxicological practice would place greater emphasis on the results of human studies.

Health concerns about the occurrence of PCBs in building materials are based on the assumption that PCBs do cause human cancer; yet there is no scientific evidence to support this contention. It is the opinion of the author that decisions to undertake expensive interior PCB abatement projects with the objective of reducing possible adverse health effects be carefully evaluated to assess whether they are truly cost-effective.

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